Intern. J. Neuroscience, 1993, Vol. 71, pp. 71–85
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Printed in the United States of America

MODIFICATION OF ACTIVATION AND EVALUATION PROPERTIES OF NARRATIVES BY WEAK COMPLEX MAGNETIC FIELD PATTERNS THAT SIMULATE LIMBIC BURST FIRING

PAULINE M. RICHARDS, MICHAEL A. PERSINGER, and STAN A. KOREN

Behavioral Neuroscience Laboratory, Department of Psychology, Laurentian University, Sudbury, Ontario, Canada P3E 2C6

(Received October 26, 1992)

In two separate experiments a total of 71 volunteers were asked to generate spontaneous narratives that were scored automatically by the *Whissell Dictionary of Affect*. During the narratives, weak (1 microT; 10 mG) magnetic fields were applied briefly through the temporal planes. In Experiment I, subjects who were exposed to simple sine wave or pulsed fields generated more scorable words that indicated lower activation and evaluation than sham-field conditions. In Experiment II subjects exposed to a computer-generated wave form, designed to simulate neuronal burst firing, generated narratives dominated by more pleasantness and less activation than a reference group. The possibility that this approach could be utilized to study the affective dimension of language selection was indicated.

Keywords: Affect; magnetic field; narrative; cognition; limbic; burst firing; brain.

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Research in psycholinguistics has suggested that a speaker generates an abstract plan that reflects the general framework or intention. As described by Hoffman (1986), the plan is then transformed into lower level representations such as syntactic units and phonetic strings. Whereas the processes by which the logical and inferential selection of words to occupy these representations have been pursued vigorously, the factors that influence the affective dimensions of discourse planning have been investigated less frequently.

Bear (1979) has developed a neurocognitive model of sensory-limbic hyperconnectionism. He argues that people whose deep temporal lobe structures are electrically labile, such as displayed by some limbic epileptic patients, experience a widening and deepening of affect within cognitive domains. This enhancement of the affective dimension influences their perceptions as well as the syntactic structure and metaphorical composition of their verbal behavior. Consequently the language of these patients is often described as replete with emotional words, viscousness or loquaciousness (Hermann, 1978; Hoeppner, Garron, Wilson and Koch-Weser, 1987).

Persinger and his colleagues (see, for example, Makarec and Persinger, 1990; Persinger and Makarec, 1987a) have been investigating the hypothesis that a continuum of "temporal lobe lability" exists within the normal population. The hypothesis, which is an extension of Bear's sensory-limbic hyperconnectionism and Landon and Fischer's (1970) conception of the language of creative performance, states that people who display less severe homologues of temporal lobe signs and symptoms (temporal lobe lability) display widened affect. It is manifested by interests in prose,

Send correspondence to: Dr. M. A. Persinger, Behavioral Neuroscience Laboratory, Laurentian University, Ramsey Lake Road, Sudbury, Ontario, P3E 2C6, Canada.

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poetry, metaphorical texts and by elevated and widened affective descriptions of subjective experiences. The positive correlation between numbers of temporal lobe signs and the pleasantness but not the activity of words within narratives that were generated by normal subjects within a free-associative setting (Ruttan and Persinger, 1989) supports this hypothesis.

The development of the *Dictionary of Affect* by Whissell (1989) and her colleagues (Fournier, Dewson and Whissell, 1986; Sweeney and Whissell, 1984; Whissell and Dewson, 1986; Whissell, Fournier, Pelland, Weir and Makarec, 1986) has allowed quantitative evaluation of this hypothesis. The dictionary included approximately 4500 English words that have been used by different experimenters (Conte and Plutchik; 1981; Russell, 1980) and common English words with affective connotations. Each word is described in terms of a score along the dimension of arousal or activation (mean = 4.0, standard deviation = 1.00; range 1–7) and a second score along the dimension of pleasantness or evaluation. Both scores are based upon ratings provided by subjects.

The dictionary is most accurate when applied to passages or lists (as opposed to single words), because it allows for the evaluation of the affective tone of the entire passage or narrative (Whissell, 1989). Application of the dictionary, for example to biblical and secular passages (Whissell and Dewson, 1986), supports the supposition of Russell (1980) that emotional (affective) space is indeed bipolar and two dimensional. One dimension ranges from bad/unpleasant to good/pleasant while the other ranges from calm/passive to aroused/active.

Correlative to this work has been an attempt to induce weak, minimally disruptive electric currents within the deep structures of the temporal lobes by applying *external* magnetic fields along the temporal plane of the scalp. Whereas traditional wave shapes produce minimal effects (except at very high and potentially hazardous intensities), complex wave forms that are more closely related to the endogenous neuronal firing patterns may be a means by which to experimentally manipulate affect. This approach assumes that neuronal ensembles respond more to the *temporal structure* of electromagnetic impulses than to the intensity of "empty" variations such as continuous trains of sine-waves.

The amygdala and the hippocampus have been targeted because they display the lowest electrical threshold of brain tissue (Stevens, Mark, Erwin, Pacheco and Suematsu, 1969). Although *direct* stimulation of these deep temporal lobe structures during surgery is well known to evoke enhanced meaningfulness and affect (Horowitz and Adams, 1970; Mahl, Rothenberg, Delgado and Hamlin, 1964; Weingarten, Cherlow and Holmgren, 1977), these changes may not be unique to epileptic patients. There is now evidence of a continuum of limbic lability or sensitivity within the normal population (Persinger and Makarec, in press; 1987; Roberts, et. al., 1990). People who score along the upper portions of this continuum frequently experience all of the phenomenological themes that are evoked by direct limbic stimulation.

Previous experiments have shown that the application of pulsed, 4–5 Hz complex waves to the temporal region while the subject is listening to a narrative (developed by Fredericksen, 1975) evoked partial amnesia (Persinger and Nolan, 1985), a phenomena that was not evoked by exposure to traditional stimulus patterns such as sine-waves or square waves. Shifts in recollection from verbatim recall to inferential substitutions for the narrative were also noted in other experiments (Michaud and Persinger, 1985). For example, the direct recall of "Jill jumped over a crack in the sidewalk" is the phrase verbatim. An inference series of the sentence might be "Jill *skipped* over the crack in the *pavement*".

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Subsequent studies indicated that the influence of these weak fields upon narrative composition was most effective when *spontaneous* narratives concerning on-going cognitive processes were encouraged by partial visual and auditory deprivation (Ruttan, Persinger and Koren, 1990). Changes in experiential reports during externally applied, pulse-form magnetic fields were most evident in individuals who displayed the greatest indications of temporal lobe sensitivity or lability. Both the existence of the continuum of temporal lobe sensitivity and the relatively weak effects of the field treatments emphasized the importance of quantitative measurement.

The following experiments indicate that brief exposures of the temporal lobes to weak 4 Hz brain-relevant magnetic fields modifies the affective tone of narratives generated by the subject during the exposure. Experiment I replicates previous work (Ruttan, et. al., 1990); subjects exposed to weak cerebral magnetic fields with simple wave configurations for brief periods reported more scorable emotional words but no differences in affective tone of those words relative to subjects who were placed in sham-field conditions. Experiment II shows that exposure to a complex field pattern that is similar to that which produced opiate release in non-human animals significantly increases the pleasantness but lowers the activation (calm/passive) tone of spontaneous narratives.

EXPERIMENT I

Method

Subjects A total of 34 undergraduate university students participated in the experiment for credit in an introductory psychology course. Each subject was tested in an individual session of approximately 45 min; there were 11 males and 23 females.

Stimuli and Apparatus The magnetic fields were generated either by a Heath Schlumberger Function Generator or by a Zenith 159 computer. Square-wave output from the first device was passed through a filter that generated a pulse form (Figure 1A) at the beginning and at the end of each square wave (maximum derivative). The signal from the computer was created by software (Persinger, Koren, Makarec, Richards and Youlton, 1990) that produced an escalating positive feedback wave pattern (Figure 1B). Signals from both sources were amplified by a digital-to-analogue converter (DAC) and a d.c. (operational) amplifier. The signal source was sent to the signal distribution interface (semiconductor switches) that was controlled by a Gebrands sequencer.

From the sequencer the signal was sent through the walls of a standard industrial acoustic chamber and was interfaced with two sets of four solenoids (250 ohm coils from 5 V DC relays, with the reed removed and replaced with a small steel finishing nail). Each set was embedded along an ellipsoid on each side of a medium size motorcycle helmet. The long axis of the ellipsoid was at the level of the mid-temporal lobes of the average subject. Because the commutator shifted the field sequentially to each solenoid every .5 sec, the focus of the magnetic field rotated spatially around the ellipsoid once every 2 seconds. The rotation frequency was selected because: 1) of its similarity to the endogenous oscillation patterns of glial cells (Persinger, Ludwig and Ossenkopp, 1973) and 2) rats exposed to .5 Hz magnetic fields display changes in emotional behaviors and analgesic thresholds (Persinger, 1974), often within only 30 minutes of exposure (Kavaliers and Ossenkopp, 1985).

When the solenoids were activated, the field strength along the external edge of the skull was 20 to 30 milligauss (mG); within the space between (approximate mid-

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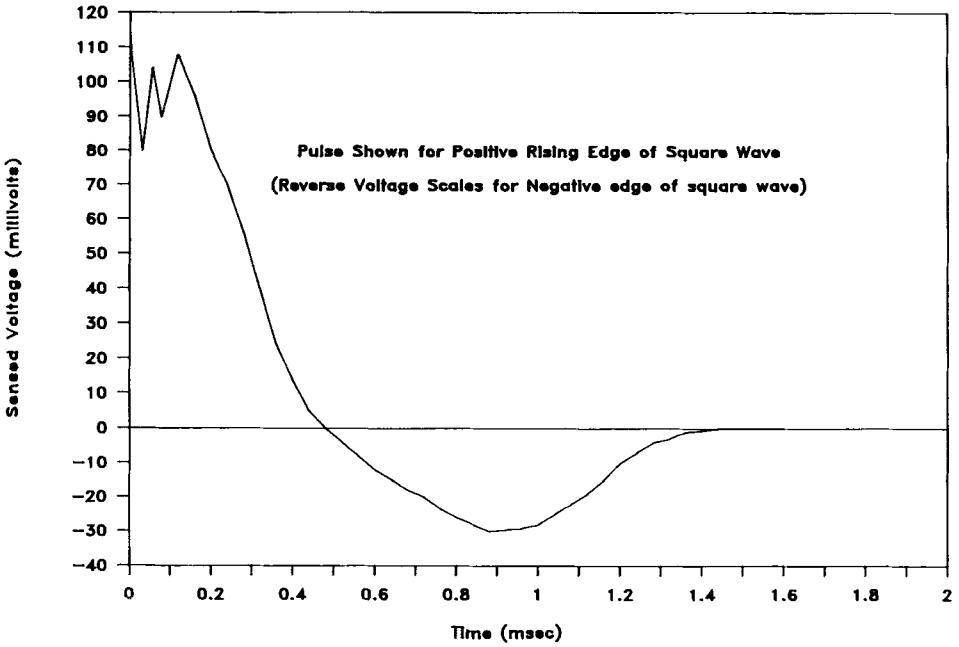

FIGURE 1A Shape of the pulse that was created by filtering a standard square wave.

line of brain) the four pairs of solenoids the magnetic field strength [as measured by a Model 113-2 power meter (verified with a Metex-3800 multimeter and probe); Electric Field Measurement, Rte 183, W. Stockbridge, MA 01266; 413-673-1929] varied between 2 mG to 10 mG. Within the same plane, at the position of the frontal lobes and occipital lobes, the intensity was about 1 to 3 mG. The variation in intensity occurred every 2 seconds at any particular point of measurement and was associated with the rotating shift (produced by the commutator) in field presentation between each pair of solenoids. Background field strengths (within the 1 Hz to 1 kHz range) were less than .1 mG within the chamber.

Procedure Each subject was asked to sit within a comfortable chair that was housed within the acoustic chamber. They were told that the experiment was concerned with imagery and that what was stated within the chamber was confidential. The subject was instructed to report all phenomenological experiences even if they appeared strange or trivial; in order to record the statements a lapel microphone was attached. After placing two halves of a ping-pong ball, lined with cotton and fashioned as goggles over the subject's eyes, the helmet containing the solenoids was fixed around the subject's head. Before leaving the chamber and shutting the door, a red light was switched on and a tape containing exotic sounds was activated. The tape has been used previously to promote imagery and to mask any potential equipment noise.

During the subsequent 30 minutes the subject's comments were recorded. An EEG lead from the helmet to a model 79 Polygraph verified the presence or absence of the field. Subjects were assigned in a quasi random fashion to one of three treatment conditions: sham field, 4 Hz simple spike-wave (from the function generator) or 4 Hz complex wave (from the computer). The fields were activated every alternative

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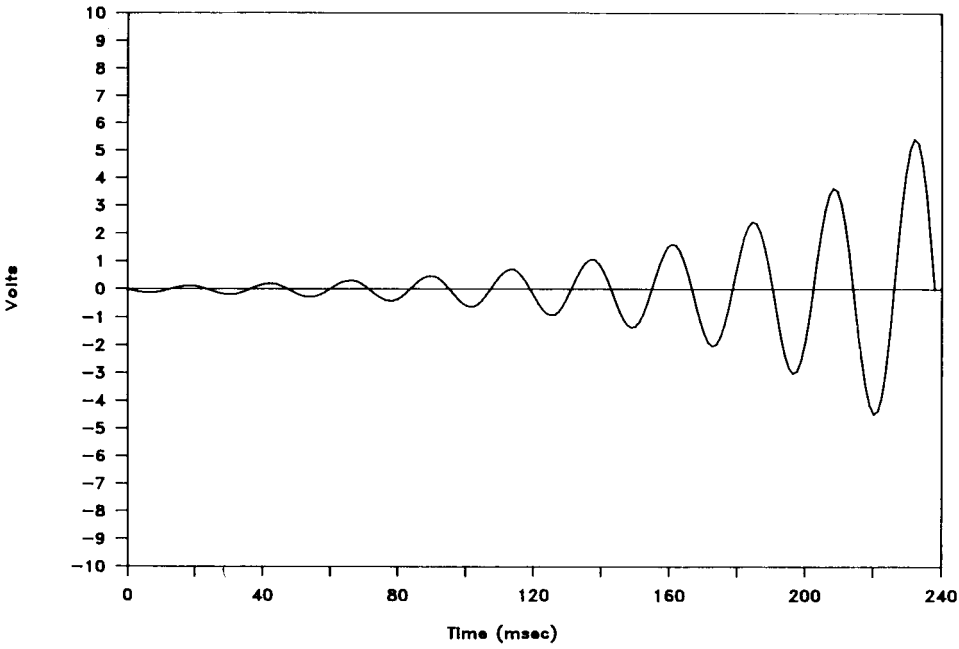

FIGURE 1B Shape of the escalating (positive) sine wave signal that was generated by computer software.

5 minutes such that there were 3 pairs of field-off and field-on intervals. For the sham field treatment, the same procedures were followed except the interface between the field sources and the helmet had been disconnected. At the end of the session, the equipment was removed from the subject and he or she left the experimental area.

The taped narratives were transcribed into computer-ready format for each subject. Because of the variable narrations of the subjects all words displayed during all three of the no field conditions were combined and all of the words displayed during the field-on conditions were combined. The words emitted during the field-off and field-on conditions (or the equivalent period for the sham-field exposed subjects) were analyzed automatically by the Whissell dictionary. The output for each subject contained the numbers of scorable words and a mean of the activation and the evaluation scores for all words for the off and on field conditions. Because of the range in fluency between subjects log (base 10) transformations were computed for the total numbers of words (+1) per minute for each subject for the off and on conditions.

All statistical analyses involved SPSSX software and a Vax 4000 computer. The primary design for the assessment of the effects of the fields upon emotional ratings of words was a four way analysis of variance (MANOVA, SPSSX) with two levels repeated (field off-on; activation-evaluation scores) and two non-repeated: treatment (sham, 4 Hz simple and 4 Hz complex wave) and sex. Variants of these analyses for numbers of words emitted and post hoc analyses were also completed.

RESULTS AND DISCUSSION

The means and standard deviations for the $\log_{10}$ of the numbers of words per minute for the no field periods (combined) and the field periods (combined) for the subjects

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TABLE 1
Means and standard deviations for the $\log_{10}$ of the numbers of scorable words emitted and their activation and evaluation scores for subjects exposed to either the sham, 4 Hz simple wave or 4 Hz complex intracerebral magnetic field condition.

		Field Off		Field On	
		Log_0^1 of words/min			
Condition	*n*	*M*	SD	*M*	SD
Sham	12	.15	.24[a]	.11	.17[a]
4 Hz Simp	10	.56	.48[b]	.43	.32[b]
4 Hz Comp	12	.66	.72[b]	.50	.24[b]

		Emotional Ratings							
		Field Off				Field On			
		Activat.		Evaluat.		Activat.		Evaluat.	
	n	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Sham	5	4.09	.53	4.73	.32	4.47	.32[a]	4.95	.32[a]
4 Hz Simp	9	4.17	.37	4.71	.17	4.06	.18[b]	4.54	.23[b]
4 Hz Comp	12	4.04	.20	4.68	.17	3.99	.21[b]	4.57	.14[b]

a vs b $p < .01$

who were exposed to either the sham field, simple 4 Hz spike-wave or complex 4 Hz waves are shown in Table 1. Chi-square analyses, comparing those that reported less than 5 words per block to those who talked frequently, were statistically significant [Chi-square (2) = 14.29, $p < .001$] and were due primarily to the less frequent responding (42% of the subjects) in the sham field group compared to the two field exposed groups (90% and 100%, respectively).

MANOVA as a function of field condition (on, off), the three field treatments and sex indicated a statistically significant treatment [$F(2, 28) = 7.48$, $p = .003$] effect and field on-off [$F(1, 28) = 29.38$, $p < .001$] repeated measure effect. The significant treatment effect was due to the more frequent statements reported by subjects who were exposed to either field condition relative to the sham field exposed groups.

The significant on-off effect was due to the decrease in spontaneous conversation when the fields were present compared to the periods when they were absent. The absence of a significant interaction between the field condition and the off-on intervals suggests that this effect was primarily an artifact of duration of exposure. In fact *post hoc* analyses of the ratio of words stated during the on to the off conditions for each subject indicated no statistically significant group differences [$F(2, 31) = 2.32$, $p > .05$]; the ratios for the three groups were: .93, .82 and .72, respectively. None of the other main effects or interactions were statistically significant.

Analyses of the activation and evaluation ratings of all of the words used during the off and on periods for the three conditions revealed a statistically significant group difference [$F(2, 20) = 5.20$, $p = .02$], a group by on-off interaction [$F(2, 20) = 4.47$, $p = .02$] and an activation vs evaluation score difference [$F(1, 20) = 86.93$, $p < .001$]. As indicated in Table 1, the latter was due to the relative decreased activation and evaluation scores for words displayed by subjects in both field treatments relative to the sham-field group. However the scores of the sham field group

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were determined by only 5 subjects because of the failure for more than 50% of this group to report subjective experiences.

Additional 4 way analyses of variance with two factors repeated (activation-evaluation; off-on) and two non-repeated (4 Hz simple vs complex) and (male vs female), in order to remove the effects from the sham field group, revealed that the field off-on effect was not statistically significant [$F(1, 17) = 3.86$, $p = .07$]. Except for the significant [$F(1, 17) = 127.34$] difference between activation and evaluation scores for the words, there were no other significant effects.

EXPERIMENT II

Method

Subjects A total of 37 university undergraduates participated in the experiment for credit in an introductory or second year psychology course; there were 18 males and 19 females.

Stimuli and Apparatus The same equipment that was utilized in Experiment I was employed in this experiment. However the signal shape generated by the computer was changed to simulate the burst-firing pattern of amygdaloid neurons. The pattern was created by a simple conversion of a series of numbers between 0 and 255 to voltage output; values below 127 were negative polarity while those above 127 were positive polarity. The duration of each of the 250 successive temporal points that constituted the wave were programmable. We selected 1 msec; this meant that each voltage option lasted for 1 msec + 190 microsec (the response latency of the computer). This meant that one cycle of the program required 275 millisec, resulting in 3.7 repetitions per second.

Fidelity of the signal that was presented through the pairs of small solenoids within the helmet was determined by placing a similar solenoid on the surface of the helmet, 5 cm behind the array (approximately P3). Both oscilloscopic (Tektronix Model 561B) and EEG strip chart recordings indicated complete fidelity for the 11 transits per cycle; however, the weaker amplitude variations between −1 V and +1 V around the zero polarity displayed a much weaker point-to-point correlation of about .70.

The field strengths that were generated through the helmet containing the solenoids were slightly higher than those reported in the previous experiment. Along the edge of the skull the field strengths were 20 mG to 40 mG. Within the space between the sets of solenoids (midline of brain), the values varied between 8 mG and 11 mG (.8 to 1.1 microT). At the level of the frontal lobes and occipital lobes, the field strengths ranged between 1 mG and 5 mG and 3 mG to 7 mG, respectively. The variations occurred every 2 seconds due to the rotation of the field presentation (by the commutator) through the pairs of solenoids.

Procedure Each subject was asked to sit in the comfortable chair that was housed within the chamber. Procedures from Experiment I were employed with the following exceptions and additions: 1) the Astral Sounds tape was not played and 2) bipolar electroencephalographic activity was recorded continually at the level of T3/T4 and O1/O2 for each subject by the P79 Grass polygraph (the third channel was still used to verify the presence or absence of the field and established the fidelity of the wave shape). The EEG was monitored for each subject to insure that anomalous synchronized cortical discharges did not appear.

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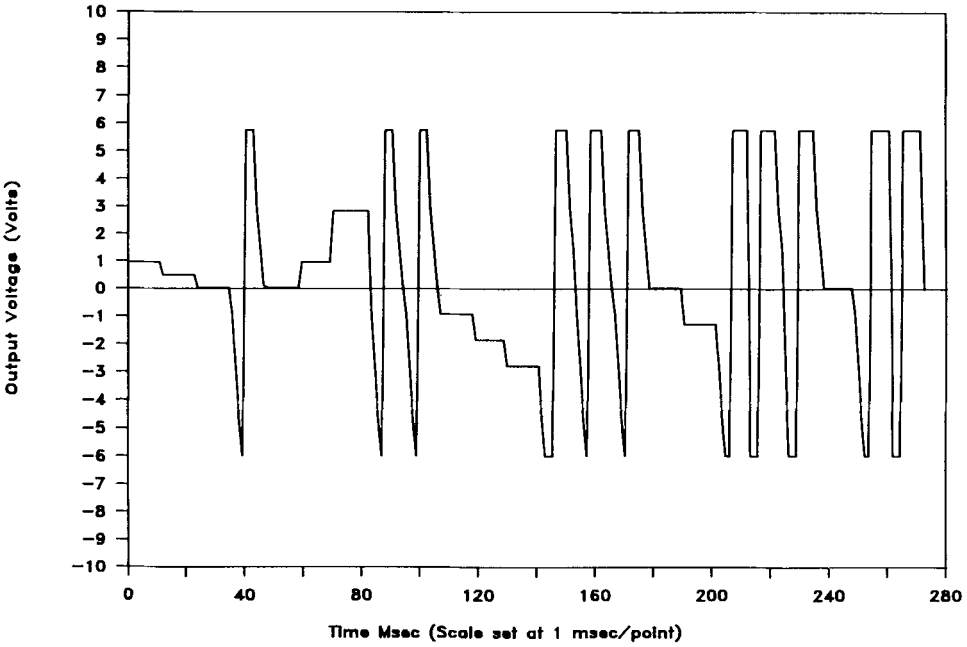

FIGURE 1C The burst-firing pattern that was generated by converting a series of preprogrammed successive numbers by computer software to voltage (Y-axis) approximately every 1 millisec. This pattern was presented continuously for 10 min or for 1 sec every 4 sec for 10 min.

Once the experimenter had applied the goggles, activated the red light and closed the door to the chamber, the experiment began. Subjects had been assigned to one of two conditions according to a sequential order that accommodated both the field condition and gender. Approximately half the numbers of males and females received the wave pattern (3.7 repetitions per sec) continuously for 10 minutes after the initial 5 minutes of baseline while the other half of the subjects received the same wave pattern except that it was presented for only 250 msec once every 4 seconds during the 10 minute period.

The latter stimulus pattern was selected in light of its putative opiate-releasing properties for rodents (Lewis, Cannon and Liebeskind, 1980) when electric shock was presented in this manner through the footpads. Because: 1) all sensory information is ultimately converted into volleys of electromagnetic impulses, 2) the temporal pattern of cutaneous stimulation is known to induce analogous patterns within appropriate cortices (Hari and Lounasmaa, 1989; Weinberg, Robertson, Crisp and Johnson, 1990), and 3) the salient information for neurons in the brain is the *temporal structure* of these electromagnetic pulses, we argued [as has E. R. John (1967; 1990)] that our experimental pattern would evoke comparable changes.

[Because current to the solenoids shifted every .5 seconds and the pulsed field was generated for only 1 second once every 4 seconds in this condition, a sinusoidal intensity period was generated at each solenoid. Direct measurement (Metex-3800; along the edge of the skull), revealed a 26 second period during which time the field strengths ranged from 1 mG to not more than 25 mG. A comparable period occurred within the midpoint of the temporal plane, within minimum-maximum values ranging from <1 mG to 10 mG.]

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TABLE 2
Means and standard deviations for the $\log_{10}$ of the numbers of scorable words emitted per minute and for activation and evaluation ratings of subjects who were exposed to the continuous 4 Hz and putative opiate-simulating pulsed field.

		Field Off		Field On	
	n	*M*	SD	*M*	SD
4 Hz Con	18	.68	.30	.69	.23[a]
4 Hz Opi	17	.54	.56	.39	.57[b]

		Emotional Ratings							
		Field Off				Field On			
		Activat.		Evaluat.		Activat.		Evaluat.	
		M	SD	*M*	SD	*M*	SD	*M*	SD
4 HzC	18	4.04	.22	4.62	.14	4.06	.12[a]	4.44	.12[a]
4 HzP	15	4.00	.19	4.62	.20	3.89	.15[c]	4.61	.11[c]

a vs b = $p < .05$
a vs c = $p < .001$

During the second half of the experiment, at the end of the first 10 minutes of field exposure, the subject was interrupted by chamber microphone and instructed to imagine that he or she was alone in a spaceship and that the only means to maintain communication and life support was to talk frequently to ground control. Narratives were transcribed and analyzed by the Whissell dictionary as noted previously. References to irritability, because of disruption from the free-associative component of the experiment and the requirement to structure and to maintain a narrative during the second half of the experiment, were determined and analyzed by chi-square. The same primary design for analyses was employed: four way analysis of variance with two levels (on-off; activation-evaluation) and two non-repeated (field continuous vs intermittent; sex) levels. Correlative analyses were also completed. Results for the first part and second part were analyzed separately.

RESULTS AND DISCUSSION

The means and standard deviations for the log base 10 of the numbers of scorable words per minute displayed during the field on and off condition for each treatment and their activation and evaluation scores are shown in Table 2. Analyses of variance indicated no statistically significant main effects or interactions between the temporal pattern of the field presentation and the numbers of scorable words.

However, statistically significant ($p < .01$) and powerful effects occurred with the emotional ratings of the words when the fields were present during the spontaneous narratives. As noted in Table 2 the subjects who received the putative opiate-releasing pulse form of the field emitted words that displayed significantly lower activation [$F(1, 31) = 12.66$, $p = .001$] scores but *higher* evaluative scores [$F(1, 31) = 15.84$, $p < .001$] than those who received the same field continuously; this result is compatible with the suggestions of Lewis et al. (1980). The eta-coefficients

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for the field effect for the activation and evaluation scores were .52 and .58, respectively; this indicates that 25% and 33% of the variance in activation and evaluation scores was attributed to the field treatments.

Four way analyses of variance further revealed a statistically significant field pattern by activation-evaluation interaction [$F(1, 30) = 14.34$, $p < .001$] that was due to the greater reduction in evaluative scores when both fields were presented relative to the decrease in activation scores. However, this interaction was due primarily to the significant field pattern by field off-on by activation-evaluation interaction [$F(1, 30) = 6.76$, $p = .01$]. This interaction was due to the reduction in activation scores for words from subjects exposed to the putative opiate releasing field pattern and the decrease in evaluation scores for words emitted by subjects who were exposed to the reference field pattern. The difference between the two emotional dimensions: activation and evaluation were again strongly apparent [$F(1, 30) = 505.62$, $p < .001$]. There were neither sex differences nor other significant interactions.

GENERAL DISCUSSION

Although cognitive psychology has emphasized the processes by which words are selected from semantic space during brief serial or single word presentations, the pursuit of factors that influence the affective dimension of the words during spontaneous language has been considered less frequently. Yet most human cognition, both privately and within social contexts, contains a substantial amount of spontaneous narrative whose emotional tone can affect both the listener and the speaker. The substantial impact of the connotative theme of discussions or narratives upon the listener's affective appreciation and memory of the event has been discussed by many authors (see for example, Frederickson, 1975; Whissell, 1989).

Simple neurocognitive models indicate that the affective dimensions of words that are selected to describe experiences should be influenced by the amygdaloid-hippocampal complex within the temporal lobes. Because words and concepts are frequently affectively charged, the probability is high that polymodal associations, perhaps mediated by the angular gyrus, subsequently link with these limbic structures (Bear, 1979). Extreme activity within these structures would be expected to generate Bear's syndrome of sensory-limbic hyperconnectionism, resulting in language that is deeply affective. Mild activity within these structures, perhaps induced by subtle shifts in the firing patterns of neuronal ensembles by the current induction from applied magnetic fields, would be expected to produce less extreme but quantitatively obvious shifts in the affective tone of language.

We have utilized the strategy of positron emission tomography (PET) in order to enhance the subjective awareness of phenomenological experiences and to minimize the contribution of random sensory input. Consequently our subjects were exposed to partial visual deprivation and either fixed or partially deprived auditory input. We assumed, as does PET technology, that the cognitive instructions and sensory modality can radically affect which portion of the brain is activated. If this assumption is valid then: 1) we would expect masking of the field effect that was observed in this study during routine sensory stimulation (such as sitting in a classroom) and 2) very specific interactions between applied fields and conditions that selectively activate neurons within the temporal lobes.

Results of the present study suggest that weak current patterns, induced within the brain at the level of the temporal lobes by complex wave magnetic fields, altered the occurrence of experiences as well as the affective tone of the words that were

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"selected" to describe these experiences. Experiment I showed that subjects exposed to brief trains of 4 Hz spike-wave and complex wave fields selected words that were less active and less pleasant than those who were exposed to the sham field condition. This effect was *only* evident when the fields were present but not during the interfield durations.

On the other hand the highly significant increase in verbal fluency (scorable words emitted) by subjects exposed to the magnetic fields relative to sham controls was evident during the field on and off conditions. The sustained difference is likely to reflect the confounding effects from averaging fluency within no field conditions between two field presentations (e.g., potential perseveration from the previous field exposure) and the fluency during the initial no field condition. These differences suggest a dissociation between fluency and affective quality of the narrative.

Experiment II indicated that the emotional tone of narratives could be enhanced in pleasantness and reduced in activation (more relaxation/passivity) when a specific wave form, suspected to encourage opiate-related analgesia in rats, was applied (1 sec every 4 sec) along the temporal lobes. The same wave pattern, generated continually, did not elicit the change in emotional tone. The simultaneous decrease in activation scores and increase in pleasantness scores for the first group was commensurate with the effects of a mild hedonic stimulation. As might be expected in the latter setting, verbal fluency decreased relative to the reference group only during the field presentation.

The statistical strength of the group differences between a weak field presented for 1 sec every 4 sec for 10 min relative to the same field presented continuously for 10 min is remarkable. At this time there is no reliable manner in which to determine if the effect was elicited by the specific pattern of the applied field within the deep temporal lobe structures or by indirect consequences, such as the release of endogenous opioids.

Failure to exclude one of the two options does not necessarily diminish the validity of the hypothesis that subtle alterations in activity of the amygdaloid-hippocampal complex influenced the emotional tone of words within spontaneous narratives. Copious concentration of delta opioid receptors have been documented in this region and the associated temporal cortices (Quirion and Pilapil, 1991). These receptors presumably mediate the hedonistic rather than the analgesic correlates of opioid activity.

The possibility that the effects were generated by mechanical artifacts is not likely. Although some subjects reported they heard "sounds," neither the emotional tone of their words nor their responses on an exit questionnaire differed from subjects who did not report this experience. In other experiments we (Persinger, et. al., 1991) found that more frequent periods of beta activity over the temporal lobes are generated during the intermittent compared to the continuous field presentations. This result is commensurate with the conclusions by Berridge and Fentress (1985) that differential activation of beta activity was found most strongly over the temporal areas for emotionally (positive or negative) significant tasks but over the parietal areas for cognitive tasks.

In addition we have found the results of this research during the last 10 years to be internally consistent. For example, a reanalysis of the Persinger and Nolan (1985) study indicated that volunteers who received 1 mG, magnetic pulses along the left hemisphere while listening to a 3 minute narrative, displayed more significant impairment of its recall than those who received the same stimulation along the right hemisphere. Pulsed magnetic fields that have been applied bilaterally along the more anterior planes of the temporal lobes have been associated with more olfactory than visual experiences while the opposite pattern has been reported when the same fields

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were presented along the posterior planes. This result is compatible, in principle, with the structural organization of the temporal lobes along the rostral-caudal axis.

Because the narratives in the present study were not transcribed or evaluated by the Whissell Dictionary of Affect until after the experiment was completed and the person (first author) who tested the subjects was not familiar with the hypothesis, the likelihood of subtle cuing is very small. The similarities of the absolute scores of both experiments during the no-field conditions and these scores with those reported in other contexts (Whissell, 1989) suggest this measure of emotional tone and the field-exposure methodology might be further utilized to study affective dimensions of spontaneous narratives.

That relatively weak fields were required to evoke these changes does not necessarily challenge their validity. Whereas significant changes in DNA synthesis may require several hours of exposure to field strengths within the microT range (Liboff, Williams, Strong and Wistar, 1984), alterations in RNA transduction require only 45 minutes of stimulation (Goodman, Bassett and Henderson, 1983). Experimental and correlational evidence indicate that some structures, such as the mammalian pineal organ, respond to brief (a few minutes) magnetic field fluctuations in the order of 50 to 1000 nT (Semm, 1988; Wilson, et. al., 1990). The major response is suppression of melatonin synthesis.

To date there have been no experiments published that have attempted to evaluate the discharge threshold of aggregates of neurons within the limbic system during brief applications of extremely low frequency magnetic fields. However, seizure thresholds may be lowered after less than an hour of 10 to 15 nT perturbations in geomagnetic activity (Keshavan, et. al., 1981). Nocturnal hallucinations, indicative of lowered limbic discharge thresholds, are associated with an average 15 to 20 nT increase in geomagnetic activity during the 24 hr period of the experience (Persinger, 1988); comparable increases in geomagnetic activity are moderately correlated with decreases in convulsive thresholds for human patients (Rajaram and Mitra, 1981).

Entrainment of EEG activity in response to brief ELF exposures has been reported in both nonhuman and human primates (Subrahmanyam, Narayan and Srinivasan, 1985). We (Persinger and Makarec, 1987b) have reported one case in which the person learned to associate the application of 4 Hz (5 mG or 500 nT) but not 1 Hz or 7 Hz magnetic fields of comparable intensity with specific, subsequent figural stimuli. Within the range of typical experimental extremely low frequency magnetic fields, the pattern of the wave and the intensity window are important for optimal responding rather than the gross magnitude of the magnetic field (Adey, 1986; Blackman, 1990).

We selected the "burst-firing" pattern because it simulated the natural firing pattern of amygdaloid neurons. Assuming the most parsimonious process, resonance interaction, we reasoned that application through the temporal lobe would presumably recruit susceptible neurons into a functional ensemble. Because of the low firing threshold and the potential for recruitment into these ensembles, amygdaloid-hippocampal neurons should have been preferentially affected. As a result, the affective component rather than the categorical component (Edelman, 1989) of subjective experience would be more effected. The shift, that would simulate the profile of people who normally display increased temporal lobe lability (Makarec and Persinger, 1990; Ruttan and Persinger, 1989) would enhance the connotative dimension of words without changing the basic syntax (Persinger and Makarec, 1991).

Although identification of the physical chemical bases of cognitive phenomena is not necessarily required in order to study them, we feel that phenomena across levels of discourse are complimented without evoking reductionism. In this context, we

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suspect that the chemical correlate of the resonance interaction between applied, appropriate neuron-relevant magnetic field patterns and neuronal activity is very likely to involve the type of fast transients in calcium concentration that are associated with epileptic processes (Pumain, Kurcewicz and Louvel, 1983).

Recent theoretical developments now refute the traditional concept of the thermal noise limit for weak electric current induction; a special condition emerges if pulsed fields are utilized (Weaver and Astumian, 1990). According to the ion cyclotron resonance (ICR) model as described by Liboff, McLeod and Smith (1990), specific ions display specific resonance frequencies. Weak externally applied magnetic fields that display these frequencies can affect mobility of a specific ion. Calcium movement into cells following brief exposures to pulsed magnetic fields has been documented (Blackman, 1990); the effect peaks within 10 to 15 minutes of field exposure (Adey, 1986).

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REFERENCES

Adey, W. R. (1986). The sequence of energetics of cell membrane transductive coupling to intracellular enzyme systems. *Bioelectrochemistry and Bioenergetics, 15*, 447–456.

Bear, D. M. (1979). Temporal lobe epilepsy- a syndrome of sensory-limbic hyperconnection. *Cortex, 15*, 357–384.

Berridge, K. C. & Fentress, J. C. (1985). EEG alpha activity reflects attentional demands, and beta activity reflects emotional and cognitive processes. *Science, 228*, 750–749.

Blackman, C. F. (1990). ELF effects on calcium homeostasis. In B. W. Wilson, R. G. Stevens & L. E. Anderson (eds.) *Extremely low frequency electromagnetic fields: the question of cancer*. (pp. 187–208) Columbus (Ohio): Battelle.

Conte, H. R. & Plutchik, R. (1981). A circumplex model for interpersonal personality traits. *Journal of Personality and Social Psychology, 40*, 701–711.

Edelman, G. M. (1989). *The remembered presence: a biological theory of consciousness*. N.Y.: Basic.

Fredericksen, C. H. (1975). Representing logical and semantic structure of knowledge acquired from discourse. *Cognitive Psychology, 7*, 371–458.

Fournier, M., Dewson, M. & Whissell, C. (1986). The dictionary of affect in language: VI. "Sensationalism" defined in terms of affective tone. *Perceptual and Motor Skills, 63*, 1073–1074.

Goodman, R., Bassett, C. A. L. & Henderson, A. S. (1983). Pulsing magnetic fields induce cellular transcription. *Science, 220*, 1283–1285.

Hari, R. & Lounasmaa, O. V. (1989). Recording and interpretation of cerebral magnetic fields. *Science, 244*, 432–436.

Hermann, B. P. (1978). Equipotentiality, preparedness, and the sensory-limbic hyperconnection hypothesis. *Cortex, 14*, 451–453.

Hoeppner, J. B., Garron, D. C., Wilson, R. S. & Koch-Weser, M. P. (1987). Epilepsy and verbosity. *Epilepsia, 28*, 35–40.

Hoffman, R. (1986). Verbal hallucinations and language production process in schizophrenia. *The Behavioral and Brain Sciences, 9*, 503–548.

Horowitz, M. J. & Adams, J. E. (1970). Hallucinations on brain stimulation: evidence for revision of the Penfield hypothesis. In W. Keup (ed). *Origins and mechanisms of hallucinations* (pp. 13–22). New York: Plenum.

John, E. R. (1967). *Mechanisms of Memory*. N.Y.: Academic

John, E. R. (1990). Representation of information in the brain. In E. R. John (ed). *Machinery of the Mind*. pp. 27–56, Birkhauser: Boston.

Kavaliers, M. & Ossenkopp, K.-P. (1985). Exposure to rotating magnetic fields alters morphine-induced behavioral responses in two strains of mice. *Neuropharmacology, 24*, 337–340.

Keshavan, M. S., Gangadhar, B. N., Gautam, R. U., Ajit, V. B. & Kapur, R. L. (1981). Convulsive threshold in humans and rats and magnetic field changes: observations during total solar eclipse. *Neuroscience Letters, 22*, 205–208.

Landon, G. M. & Fischer, R. (1970). On common features of the language of creative performance and hallucinogenic-drug-induced creative experience. In W. Keup (ed). *Origins and mechanisms of hallucinations* (pp. 413–459). New York: Plenum.

RIGHTSLINK

Lewis, J. W., Cannon, J. T. & Liebeskind, J. C. (1980). Opioid and nonopioid mechanisms of stress analgesia. *Science, 208*, 623–625.

Liboff, A. R., Williams, T., Strong, D. M. & Wistar, R. (1984). Time-varying magnetic fields: effect on DNA synthesis. *Science, 223*, 818–820.

Liboff, A. R., McLeod, B. R. & Smith, S. D. (1990). Ion cyclotron resonance effects of ELF fields in biological systems. In B. W. Wilson, R. G. Stevens & L. E. Anderson (eds.) *Extremely low frequency electromagnetic fields: the question of cancer* (pp. 251–289). Columbus (Ohio): Batelle.

Mahl, G. F., Rothenberg, A., Delgado, J. M. & Hamlin, H. (1964). Psychological responses in the human to intracerebral electrical stimulation. *Psychosomatic Medicine, 26*, 337–368.

Makarec, K. & Persinger, M. A. (1990). Electroencephalographic validation of a temporal lobe signs inventory in a normal population. *Journal of Research in Personality, 24*, 323–337.

Michaud, L. Y. & Persinger, M. A. (1985). Geophysical variables and behavior: XXV. Alterations in memory for a narrative following application of theta frequency electromagnetic fields. *Perceptual and Motor Skills, 60*, 416–418.

Persinger, M. A. (1974). *ELF and VLF Electromagnetic Field Effects*. N.Y.: Plenum.

Persinger, M. A. (1988). Increased geomagnetic activity and the occurrence of bereavement hallucinations: evidence for melatonin-mediated microseizuring in the temporal lobe? *Neuroscience Letters, 88*, 271–274.

Persinger, M. A., Koren, S. A., Makarec, K., Richards, P. & Youlton, S. (1991). Differential effects of wave form and the subject's possible temporal lobe signs upon experiences during cerebral exposure to weak intensity magnetic fields. *Journal of Bioelectricity 10*, 141–148.

Persinger, M. A., Ludwig, H. W. & Ossenkopp, K.-P. (1973). Psychophysiological effects of extremely low frequency electromagnetic fields: a review. *Perceptual and Motor Skills, 36*, 131–159.

Persinger, M. A. & Makarec, K. (1987). Temporal lobe epileptic signs and correlative behaviors displayed by normal populations. *The Journal of General Psychology, 114*, 179–195.

Persinger, M. A. & Makarec, K. (1987). Possible learned detection of exogenous brain frequency electromagnetic fields: a case study. *Perceptual and Motor Skills, 65*, 444–446.

Persinger, M. A. & Makarec, K. (1991). Interactions between temporal lobe signs, imaginings, beliefs and gender: their effect upon logical inference. *Imagination, Cognition and Personality, 11*, 149–166.

Persinger, M. A. & Makarec, K. (in press). Complex partial epileptic-like signs as a continuum from normals to epileptics: normative data and clinical populations. *Journal of Clinical Psychology*.

Persinger, M. A. & Nolan, M. (1985). Partial amnesia for a narrative following application of theta frequency electromagnetic fields? *Journal of Bioelectricity, 4*, 481–494.

Pumain, R., Kurcewicz, I. & Louvel, J. (1983). Fast extracellular calcium transients: involvement in epileptic processes. *Science, 222*, 177–179.

Quirion, R. & Pilapil, C. (1991). Distribution of multiple opioid receptors in the human brain. In F. A. O. Mendelsohn and G. Paxinos (eds). *Receptors in the human nervous system*. (pp. 103–122.) N.Y.: Academic.

Rajaram, M. & Mitra, S. (1981). Correlation between convulsive seizure and geomagnetic activity. *Neuroscience Letters, 24*, 187–191.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1161–1178.

Ruttan, L. A. & Persinger, M. A. (1989). Temporal lobe signs and enhanced pleasantness scores for words generated during spontaneous narratives. *Perceptual and Motor Skills, 69*, 1101–1102.

Ruttan, L. A., Persinger, M. A. & Koren, S. (1990). Enhancement of temporal lobe-related experiences during brief exposures to milligauss intensity extremely low frequency magnetic fields. *Journal of Bioelectricity, 9*, 33–54.

Semm, P. (1988). The magnetic detection system of the pigeon: involvement of pineal and retinal photoreceptors and the vestibular system. In M. E. O'Connor & R. H. Lovely (ed). *Electromagnetic fields and neurobehavioral function*. (pp. 47–61). N.Y.: Liss.

Stevens, J. R., Mark, V. H., Erwin, F., Pacheco, P., & Suematsu, K. (1969). Deep temporal stimulation in man. *Archives for Neurology, 21*, 157–169.

Subrahmanyam, S., Sanker Narayan, P. V. & Srinivasan, T. M. (1985). Effect of magnetic micropulsations on biological systems: a bioenvironmental study. *International Journal of Biometeorology, 29*, 293–305.

Sweeney, K. & Whissell, C. (1984). A dictionary of affect in language: I. Establishment and preliminary validation. *Perceptual and Motor Skills, 59*, 695–698.

Weaver, J. C. & Astumain, R. D. (1990). The response of living cells to very weak electric fields: the thermal noise limit. *Science, 247*, 459–462.

Weinberg, H., Robertson, A. W., Crisp, D. & Johnson, B. (1990). Magnetic fields of the brain resulting from normal and pathological function. In E. R. John (ed). *Machinery of the Mind*. (pp. 479–511.) Birkhauser: Boston.

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Weingarten, S. M., Cherlow, D. G. & Holmgren, E. (1977). The relationship of hallucinations to the depth structures of the temporal lobe. *Acta Neurochirurgica*, Suppl. *24*, 199–216.

Whissell, C. (1989). The Dictionary of affect in language. *Emotion: theory, research and experience*: volume *4* (pp. 113–131). New York: Academic Press.

Whissell, C. M. & Dewson, M. R. J. (1986). A dictionary of affect in language: III. Analysis of two biblical and two secular passages. *Perceptual and Motor Skills*, *62*, 127–132.

Whissell, C. M., Fournier, M., Pelland, R., Weir, D., & Makarec, K. (1986). A dictionary of affect in language: IV. Reliability, validity and applications. *Perceptual and Motor Skills, 62*, 875–888.

Wilson, B. W., Wright, C. W., Morris, J. E., Buschbom, R. L., Brown, D. P., Miller, D. L., Sommers-Flannigan, R. & Anderson, L. E. (1990). Evidence of an effect of ELF electromagnetic fields on human pineal gland function. *Journal of Pineal Research, 9*, 259–269.

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